ECONOMIC ANALYSIS OF A LARGE SCALE ORAL VACCINATION PROGRAM TO CONTROL RACCOON RABIES

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Abstract: Since the late 1980s, results of oral vaccination trials in several states have provided growing evidence that this vaccination method may be effective for controlling the spread of rabies in raccoons (*Procyon lotor*). This study examines the economic feasibility of using oral vaccination on a larger scale than previous trials. We analyze the benefits and costs associated with a hypothetical barrier that would stretch from Lake Erie to the Gulf of Mexico, combining natural geographic features provided by the Appalachian Mountains with oral vaccination zones. The goal of this barrier would be to prevent the raccoon rabies variant from moving west into broader geographic regions of the United States. The costs of establishing and maintaining this hypothetical barrier are compared to the avoided costs of not having to live with raccoon rabies west of its current distribution. The westward advance of raccoon rabies, if it is not contained, is projected using simple models based on constant rates of spread. Our results show that preventing the westward movement of raccoon rabies by combining an oral vaccination program with natural barriers may be economically feasible. Discounted costs of establishing and maintaining the barrier are estimated to total between US$58 million and US$148 million. Net benefits of program implementation range between US$48 million and US$496 million for a variety of models, including ones that exclude forgone pet vaccination expenditures. The analysis also provides a framework for developing future models to explore the benefits and costs of eliminating raccoon rabies from currently affected areas.

Key Words: barrier, cost-benefit, economics, oral vaccination, ORV, *Procyon lotor,* rabies, Raboral V-RG®, raccoon.

Reported cases of animal rabies in the United States have nearly doubled in the last 30 years, with most of the increase attributable to the spread of raccoon rabies in the northeastern states. The raccoon epizootic has spread east and north from the Virginia/West Virginia border and has also converged with raccoon rabies in the Carolinas (Krebs et al. 1998). In the past 21 years, all of the mid-Atlantic and New England states have experienced at least one outbreak. The raccoon rabies epizootic front reached Maine in 1994, reflecting a movement rate of about 30 to 35 miles per year (48.3 km/yr). It was also first confirmed in northeastern Ohio in 1996 (Krebs et al. 1998). In 1999, the first three cases of raccoon rabies were confirmed in southern Ontario (MacInnes, Ontario Ministry of Natural Resources, pers com).

Several states and jurisdictions have implemented oral rabies vaccination (ORV) programs using the vaccine Raboral V-RGÒ either to attempt to halt the advance of raccoon rabies or eliminate or reduce it. These areas include: Pinellas County, Florida; Cape Cod, Massachusetts; Cape May, New Jersey; portions of New York, Vermont and Ohio, and recently, Anne Arundel County, Maryland and Fairfax, Virginia. In addition, Raboral V-RGÒ has been used with success to control rabies in coyotes (Fearneyhough et al. 1998) and gray foxes in Texas (Fearneyhough and Wilson 2000). Data from these site-specific programs provide a basis for considering larger scale control efforts.

Raccoon rabies presents a human health threat though potential direct exposure to rabid raccoons, or indirectly through the exposure of a pet to rabid raccoons. To date, there have been no known cases of rabies in humans attributable to raccoon rabies. However, the number of pets and livestock examined and vaccinated for rabies, the number of tests requested, and the number of post-exposure treatments are all greater when raccoon rabies is present. Human and financial resources allocated to rabies-related human and animal health needs also increase, often at the expense of other important activities.

The westward movement of the raccoon rabies front has slowed, probably in response to both natural geographic and man-made barriers. The Appalachian mountains and perhaps river systems flowing eastward have helped confine the raccoon variant to the eastern United States. In northeast Ohio, an ORV program has established an "immune barrier" along its border with Pennsylvania from the Lake Erie to the Ohio River near East Liverpool, Ohio that has slowed if not stopped the westward expansion of raccoon rabies. If raccoon rabies breaches this barrier, current raccoon live trapping results in Ohio (Montoney, personal communication) as well as the status of raccoons in the Midwest (Sanderson and Hubert 1982, Glueck et al. 1988, Hasbrouck et al. 1992, Mosillo et al. 1999) suggest that populations are sufficient for rabies to spread westward along a front, similar to or more rapidly (Rupprecht and Smith 1994) than it has in the eastern United States.

For this analysis we refer to two regions of the United States. The first region consists of the states that are already affected by raccoon rabies (epizootic/post-epizootic states). These are primarily the mid-Atlantic, New England, and eastern seaboard states, although

portions of Florida and Georgia in particular have had enzootic rabies for 40 to 50 years or more and may be thought of as post-epizootic states within the affected eastern US. The second region consists of the Midwest and Plains states, out to the Rocky Mountains that have never experienced raccoon variant of rabies (pre-epizootic states).

The presence of the raccoon rabies variant has been shown to dramatically increase the incidence of rabies, and may present a higher exposure risk than other variants. Krebs et al. (1998) reports that 6,563 of the 8,513 reported animal rabies cases in the United States in 1997 were from states that had experienced raccoon rabies (epizootic/post-epizootic states) and 1,238 were from states currently unaffected by the raccoon variant (pre-epizootic states). In both regions, wild animal infections were dominant. However, there were more infected domestic cats and dogs reported in epizootic/post-epizootic states than in pre-epizootic states. Of the 6,210 wild animal cases reported in epizootic region, 4,276 were raccoon cases. The epizootic states also reported more skunk, fox, and bat cases than did the pre-epizootic states.

ASSUMPTIONS

This analysis examines a hypothetical barrier against the spread of raccoon rabies. Higher elevations of the Appalachian Mountains are assumed to form portions of this barrier. This assumption is based in large part on the pattern for raccoon rabies spread from West Virginia in the late 1970s. From that focus, raccoon rabies moved generally north and east. Presumably this pattern of spread was due in part to the effect of poorer raccoon habitats at higher elevations in the Appalachians which served as natural barriers to the westerly movement of the disease (Rupprecht and Smith 1994).

In addition, models and results rely heavily on several other basic assumptions. We assume that without intervention the raccoon rabies variant would spread westward across the Midwest and Plains states. Ohio has recently encountered the raccoon rabies variant in areas near its eastern border, and established an ORV program to attempt to contain it. Ohio experienced a breach in its barrier in 1999. The barrier was subsequently widened with no additional cases of raccoon variant west of the current vaccination barrier (Smith, personal communication). Also, there has recently been evidence of raccoon rabies crossing the Alabama River and entering the western part of Alabama (W. B. Johnston, Alabama Department of Public Health, personal communication).

The second main assumption is that the consequences of the raccoon rabies variant entering the Midwest and Plains states would be similar to what has been experienced by states already affected, despite demographic and ecological differences between the affected and unaffected states. As raccoon rabies occupies a broader geographic area, there is an expectation of greater numbers of rabies cases in other wild and domestic animals, along with the increase in raccoon rabies cases. Although the pre-epizootic Midwest and Plains states collectively have a lower human population and per capita income, they have a larger land area and more domestic livestock than the states currently affected by the raccoon rabies variant. These states also have the capacity to support abundant raccoon populations (Stuewer 1943, Twitchell and Dill 1949, Urban 1970, Schinner and Gauley 1974, Sanderson and Hubert 1982, Glueck et al. 1988, Hasbrouck et al. 1992, Mosillo et al. 1999). These factors could affect the movement of the raccoon rabies variant, and the impact it has on human populations. However, without specific data on how the epizootic will spread, we assume that the impacts will be similar to the states already affected.

Additionally, we assume that current methods of oral rabies vaccination can effectively contain the raccoon rabies variant. Studies on the effectiveness of ORV in several states have shown that the methods used appear to be effective. Specifically, the ORV program in Ohio against raccoon rabies and the ORV program in Texas against coyote rabies have had good results (Fearneyhough et al. 1998, Collart 2000). Implicit in this assumption is that translocation of a rabid raccoon into the unaffected areas would not occur, or would not lead to establishment of the raccoon rabies variant as was documented in West Virginia in the 1970s (Nettles et al. 1979).

METHODS

Benefits and costs are monetized in a cost-benefit framework. Benefits are all costs, including direct medical and nonmedical costs, that would be avoided as a result of the proposed ORV program. Other indirect avoided costs such as time lost due to prophylaxis, potential adverse effects of the oral vaccine, business losses due to decreased recreational activities in affected areas, and the value of potential lost life are not included. These would all raise the expected benefit.

The benefits result from preventing the adverse effects of the epizootic, and related expenditures to manage and control it, in the pre-epizootic states. These avoided consequences include increased public education regarding raccoon rabies, a larger number of pre-exposure vaccinations and post-exposure treatments, increased compliance rates for dog and cat vaccinations, increased local animal control and surveillance activities, and increased raccoon-focused wildlife management activities. Also, laboratory staff and supply needs would increase costs.
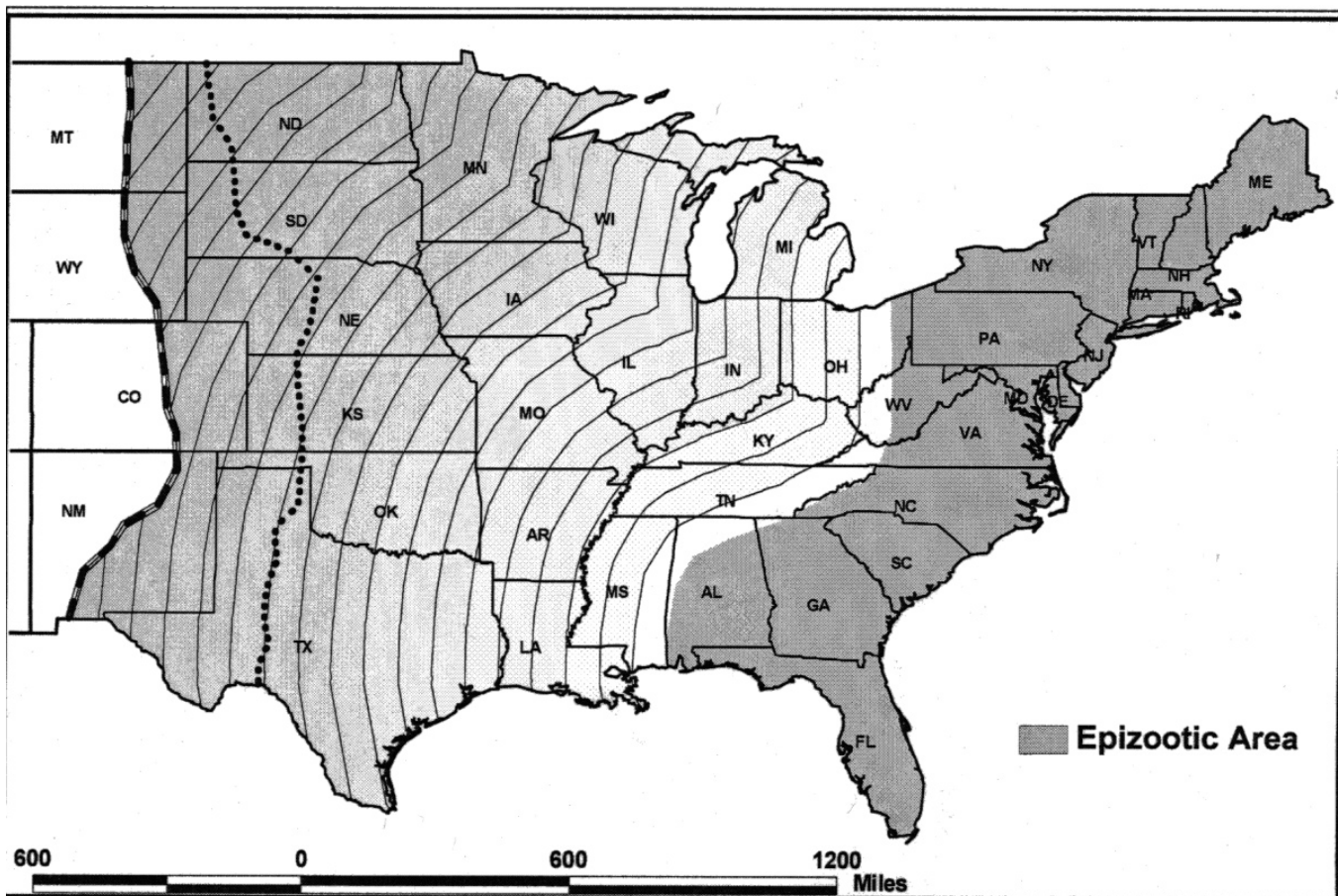
Fig. 1. Assumed rabies spread.

The study estimates the benefit of avoiding epizootic expansion as the sum of public and private expected expenses; that is, costs beyond those currently borne due to the presence of other strains of rabies. These are quantified in terms of cost savings, by comparing anticipated epizootic and post-epizootic costs to pre-epizootic rabies private costs and program expenditures. The net avoided incremental costs are then compared with the barrier program costs in deciding whether the program is economically feasible, with future benefits and costs discounted to present values. Two rates are assumed for the spread of the epizootic over a 20-year time horizon: 25 miles/year (40.23km/yr) and 75 miles/ year (120.7 km/yr) (Fig. 1).

In the analysis, the increase in number of pet vaccinations due to the epizootic is considered a forgone cost. Although routine pet vaccination is a regulatory requirement in most of the states considered here, a percentage of pets remains unvaccinated until imminent danger threatens. From a public health perspective, the resultant increased compliance as raccoon rabies becomes established is clearly good from a public health perspective. However, because these increased resource requirements would result from the emergency situation and not reflect planned action, these costs are here considered as private costs. Vaccination of pets is a major reason why few human deaths from rabies occur in developed countries and most jurisdictions continuously allocate rabies control resources for pet vaccination services and education.

MODEL

The model that is used has 2 major components. One component estimates the costs for establishing and maintaining the barrier, as well as other costs related to the proposed ORV program. The other component estimates the costs that would be incurred if raccoon rabies spread westward unchecked.

Data on the costs associated with the raccoon rabies variant were collected from a variety of sources including previous studies (Sherman 1990, Uhaa et al. 1992, Huntley et al. 1995, Meltzer 1996), reference literature (AVMA 1997, Bureau of the Census 1998, CDC 1998, NASS 1998, 1999), direct contacts with people working with raccoon rabies and oral vaccines, and a pair of surveys sent out to several state public health veterinarians. In most cases, multiple sources were used to determine mean or median values that would be sufficiently representative of the states included in the analysis. Where relevant, each element was assigned

a pre-epizootic value, an epizootic value and a post-epizootic value.

Bait, its distribution and project evaluation costs are provided in Table 1. Program costs are estimated under the following baseline assumptions. The costs of potential adverse effects of the oral vaccine program (nontarget animals affected by consuming baits, accidental human contact with the baits, etc.) are assumed to be zero. The effectiveness of vaccination programs would be validated through surveillance and testing of raccoon populations in the barrier zones (i.e., program evaluation). The evaluation cost listed also includes educational, promotional, and overhead expenses.

Table 1. Barrier and program costs.

Program cost components	Unit values
Area baited	102,650 km²
Bait density	75/km²
Bait cost (Raboral V-RG®)	US$1.30/unit
Aerial distribution cost	US$8.62/km²
Program evaluation	US$15.00/km²

The cost of the barrier is calculated annually. However, because the cost of maintaining the barrier is likely to be less than initial establishment costs, we use a lower value after the initial period. For the first 5 years we use the full program cost. This period represents a higher level of baiting over the entire barrier area. Every year thereafter we use 40% of the full program cost. This period represents a lower level of baiting as the emphasis of the program shifts primarily to monitoring and spot baiting as needed. Total discounted program costs for the planned 20-year time horizon are US$95,700,000.[1]

Determining the costs that would be avoided by establishing an immune barrier is more complex. They are calculated by estimating the spread of the raccoon rabies epizootic as a uniform movement from the bar-

[1] For this analysis we use a 7% discount rate as advised by OMB circular No. A-94 "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs" Section 8b.

rier location to the Rocky Mountains (Fig. 1). For each year of the model, a new "slice" of the pre-epizootic area would be affected. Geographic Information Systems (ESRI, ArcView GIS 3.1) are used to determine the shape of each "slice" as well as the human population within each of these areas. The cost of raccoon rabies for each area is determined by its population and base costs per 100,000 population (Table 2). The total avoided cost each year is the summation of costs that would be incurred in currently and previously affected "slices."

The data elements used to determine the costs associated with a raccoon rabies epizootic are the same as those used by Uhaa et al. (1992): animal-associated costs, human-associated costs, and other rabies-related expenditures. The most significant component of the animal cost category is the increase in pet and livestock vaccinations in response to a raccoon rabies epizootic. For dogs, this represents an increase in vaccination rates from an average of 45% vaccinated under pre-epizootic conditions, to 65% in epizootic conditions, and down to 60% in post-epizootic conditions. For cats, the vaccination rate is 23% before the raccoon rabies epizootic, 40% during the epizootic, and 25% during post-epizootic years.

For livestock, less than 0.5% are vaccinated before an epizootic. During an epizootic, vaccination rates are just over 1%, and they then drop back to less than 1% during post-epizootic years. For this study all mammalian livestock were counted together, and as a result, the costs may be somewhat skewed. The livestock figures are influenced by vaccination costs that are extremely low for swine, sheep, goats, and cattle, but higher for horses. Vaccination rates are low, but the mean cost per head for domestic animals overall is comparable to the cost of vaccinating a dog or cat. To examine the significance of avoided pet and livestock vaccination costs, they are excluded in two model variations.

The other major elements of animal-associated costs deal with surveillance and monitoring of rabies in wildlife and domestic animals. These include labora-

Table 2. Incremental costs for the avoided cost components.

Avoided cost component	Incremental epizootic US$cost/100,000	Incremental post-epizootic US$cost/100,000	US$cost/unit
Pre-exposure prophylaxis	2,800	900	300
Post-exposure prophylaxis	32,600	4,200	1.50
Surveillance	6,300	4,100	n/a
Lab costs	7,600	6,800	n/a
Case investigations	6,500	8,200	n/a
Dog vaccinations	46,000	35,000	10
Cat vaccinations	44,000	13,000	10
Livestock vaccinations	10,600	6,100	10
Educational programs	21,400	21,400	n/a

tory diagnostic costs, the costs of preparing samples for testing, and animal bite investigations. Survey results show that the cost for laboratory diagnostics appears to increase significantly when raccoon rabies enters the epizootic stage and remains high into the post-epizootic stage. This may reflect not only larger numbers of animals tested, but also more detailed virus typing and more sophisticated rabies tests, as part of an overall more intensive surveillance program.

Other animal-associated costs specified in other studies include those for domestic animal control and confinement of domestic animals suspected of having rabies (Uhaa et al. 1992, Huntley et al. 1995, Meltzer 1996, Masters 1998). These costs are excluded from our study due to a lack of information about expenditure levels. Other costs or perhaps benefits not included in this study are the wildlife conflict costs (e.g., does raccoon rabies increase or decrease costs of raccoon-related conflicts with humans?). Also not included here are damage, nuisance, and predation impacts on ground-nesting birds. These costs may be expected to decline as a result of rabies mortality in areas supporting abundant raccoon populations. If this effect does occur, it is likely to be short-term (1-3 years) until the local raccoon population recovers. Further study on this topic is required, including the impacts of the typically heightened sense of urgency associated with raccoon problems, independent of raccoon density, when rabies is documented in a specific geographic area.

Human-associated costs include the cost of pre-exposure vaccination and post-exposure treatment. In a rabies epizootic, these costs increase as more people at risk protect themselves against rabies through pre-exposure vaccinations. Post-exposure prophylaxis increases as the number of potential and actual exposures to rabies increases (Meltzer 1996, Kreindel et al. 1998).

Data on the cost and number of human pre- and post-exposure treatments were gathered primarily through surveys. Other costs associated with raccoon rabies include costs for public education, additional public health staffing, additional staff training, and additional administrative and clerical costs.

The 2 cost structures shown in Table 2 represent the somewhat cyclical nature of a raccoon rabies epizootic. Typically, when raccoon rabies enters a new area the epizootic can be intense for a few years, subside to a lower level, and then re-emerge (Trimarchi 1995, Meltzer 1996, CDC 1997). To account for this pattern, the epizootic cost structure is assumed for the first three years that raccoon rabies is new to an area. Subsequently the "post-epizootic" cost structure is used, with a switch back to the epizootic structure once every 5 years for a year.

Four model variations were evaluated. We use 25 and 75 miles per year (mpy) for the rates at which the epizootic spreads westward. Additionally, we evaluated

variations including and excluding the cost of animals vaccinated in response to the epizootic. Model A uses 25 mpy and includes animal vaccination costs. Model B uses 25 mpy and excludes animal vaccination costs. Model C uses 75 mpy and includes animal vaccinations. Model D uses 75 mpy and excludes animal vaccinations.

RESULTS AND ANALYSIS

Annual avoided costs (benefits) and program costs are discounted to present values. The final stage of the analysis involves comparing these discounted benefits and costs. The primary decision criterion is net benefits or net present value (NPV). NPV is the present value of benefits (avoided costs) gained minus the present value of program costs incurred. If NPV is positive, then the ORV program is considered economically feasible.

Net benefits for each of the 4 model variations for the total discounted program cost of US$95.7 million are economically feasible (Table 3).

Table 3. Net present values for models evaluated.[a]

Model	Net benefit (US$millions)
A: 25 mpy advance (40.2 km/yr)	202
B: 25 mpy advance (40.2 km/yr), no animal vac.	109
C: 75 mpy advance (127.1 km/yr)	496
D: 75 mpy advance (127.1 km/yr), no animal vac.	313

[a]Discount rate = 7%

To explore some alternative situations and test the robustness of the models, we conducted several types of sensitivity analysis. First, we considered a scenario in which the full program costs are used for the entire period instead of dropping to 40% after 5 years. In this case, the total discounted program cost for the planned time horizon is US$157,320,000. All of the model variations remain economically feasible (Table 4).

Table 4. Net benefits (NPV) with full program cost for entire time horizon.[a]

Model	Net benefit (US$millions)
A: 25 mpy advance (40.2 km/yr)	141
B: 25 mpy advance (40.2 km/yr), no animal vac.	48
C: 75 mpy advance (127.1 km/yr)	422
D: 75 mpy advance (127.1 km/yr), no animal vac.	259

[a]Discount rate = 7%

We examined the maximum program costs that the benefit stream would support (Table 5). This is the program cost at which net benefits are zero. When

compared to the estimated program cost of US$95.7 million, these maximum costs indicated that the program could be twice as expensive as estimated and remain economically feasible.

Table 5. Largest ORV program cost that benefits could support.[a]

Model	Maximum program cost (US$millions)
A: 25 mpy advance (40.2 km/yr)	298
B: 25 mpy advance (40.2 km/yr), no animal vac.	205
C: 75 mpy advance (127.1 km/yr)	586
D: 75 mpy advance (127.1 km/yr), no animal vac.	403

[a]Estimated program cost = US$95.7 million

To determine if the model is sensitive to the discount rate of 7%, net benefits were evaluated for discount rates of 5% and 10% (Table 6). As expected, net benefits are smaller due to the increased discount rate.

Table 6. Net benefits (NPV) for 5% and 10% discount rates.

Model	NPV 5%	NPV 10%
A: 25 mpy advance (40.2 km/yr)	281	126
B: 25 mpy advance (40.2 km/yr), no animal vac.	160	60
C: 75 mpy advance (127.1 km/yr)	615	367
D: 75 mpy advance (127.1 km/yr), no animal vac.	394	226

Monte Carlo Sensitivity Analysis

The Monte Carlo sampling technique was used to examine the robustness of model results by simulating assumed values of relevant parameters. The NPVs were estimated, running each simulation for 10,000 iterations using the risk analysis computer package @RISK for Excel (Palisade Corporation, Newfield, NY). For each iteration, the program selects input values at random from the probability distributions specified and estimates the outputs (the discounted costs and NPVs) for the program period. From this simulated data base, various measures of central tendency and percentiles are used to alleviate reliance on single point estimates. For

example, the total baited area is expected to range between 84,500 and 120,800 km^2, and this range can be more confidently applied in a simulation than a point estimate of 102,650 km^2 (Table 7).

Lacking knowledge concerning the shape of the probability distribution of these input variables, we used the uniform and the triangular distributions to define uncertainty. Both of these distributions are among the simplest means of representing uncertainty. Uniform distribution is used where one can specify only the minimum and maximum possible values for the input variable. Any numerical value is equally likely to occur within these limits. Triangular distribution is used to represent the distribution of a random variable when the most likely value is also known.

The average NPVs over 10,000 trials shown in Table 8 are close to the base calculations shown in Table 6. The coefficient of variation is low for all models tested, ranging between 0.008 and 0.038, indicating that the estimated values are stable (Table 8). Thus, the results appear to be robust, and we conclude with reasonable confidence that net economic benefits, in terms of avoided costs due to the ORV program, would be substantial.

Discounted program costs for the base model range between US$58 million and US$148 million. The expected cost is about US$95.6 million, while the median cost is about US$94.7 million. The results are not particularly sensitive to assumed aerial distribution costs. Substantially increasing the distribution cost to US$35 per square kilometer results in a cost range of between US$57 million and US$165 million, with an expected cost of about US$105.4 million and a median cost of US$104.5 million. The differences between these results and those of the base model are small considering the time period. The NPVs using the US$35 per km^2 for distribution costs are US$182 million, US$88.4 million, US$476 million and US$293 million, for models A, B, C, and D, respectively.

CONCLUSIONS

The models presented indicate that a large scale ORV program, such as the one proposed, should be economically feasible, given the program costs and avoided

Table 7. Cost components, point estimates, probability distributions and assumed range of values.[a]

Program cost components	Average values	Probability distribution	Range of values
Barrier area in km^2	102,650	Uniform	84,500-120,800
Bait density/km^2	75	Triangular	50-75-100
Bait cost/unit	US$1.30	Uniform	US$1.20-US$1.40
Aerial distribution cost/km^2	US$8.62	Uniform	US$6.92-US$10.32
Cost/km^2	US$15.00	Uniform	US$12.00-US$18.00

[a]The range of values for the uniform distributions are the minimum and maximum values and those for the triangular distribution are the minimum, most likely, and maximum.

Table 8. Net Benefits (NPV) using the Monte Carlo Sensitivity Analysis (US$million).[a]

Model	Model A	Model B	Model C	Model D
Minimum	185.00	92.10	478.00	298.00
Maximum	216.00	123.00	511.00	327.00
Mean	202.00	109.00	496.00	313.00
Standard deviation	4.10	4.11	4.07	4.07
Estimated value (from Table 3)	202.00	109.00	496.00	313.00

[a]Discount rate = 7%

cost assumptions. Results of the Monte Carlo analysis, even when we consider the uncertainty of values, indicate that the program costs remain stable. Avoided costs are driven mainly by the cost of human post-exposure prophylaxis and pet vaccinations. Estimates for these variables are calculated on a per 100,000 human population basis. As such, they depend on the speed that the raccoon rabies variant moves westward as well as the pattern and distribution of the westward spread. For this analysis we have used a uniform distribution and 2 constant spread rates. As more information becomes available about how the variant might spread westward it may be possible to add sophistication to our models and further refine projected ORV program costs and benefits.

LITERATURE CITED

AMERICAN VETERINARY MEDICAL ASSOCIATION. 1997. U.S. pet ownership and demographics source book. Center for Information Management, AVMA, Schaumburg, Illinois, USA.

CENTERS FOR DISEASE CONTROL. 1997. Update: Raccoon rabies epizootic – United States, 1996. Morbidity and Mortality Weekly Report 45: 1117-1120

CENTERS FOR DISEASE CONTROL. 1998. Compendium of animal rabies control 1998. Morbidity and Mortality Weekly Report 47:RR-9. CDC, Atlanta, Georgia, USA.

COLLART, M. 2000. Rabies update: Spring 2000. Ohio Department of Health Prevention Monthly, April/May. XXIII: 1-2.

FEARNEYHOUGH, M. G., P. J. WILSON, K. A. CLARK, D. R. SMITH, D. H. JOHNSTON, B. N. HICKS, AND G. M. MOORE. 1998. Results of an oral rabies vaccination program for coyotes. Journal of the American Veterinary Medical Association 212:498-502.

FEARNEYHOUGH, M. G., AND P. J. WILSON. 2000. The Texas oral rabies vaccination program (ORVP). Texas Veterinarian 62:18-33.

GLUECK, T. F., W. R. CLARK, AND R. D. ANDREWS. 1988. Raccoon movement and habitat use during the furharvest season. Wildlife Society Bulletin 16:6-11.

HASBROUCK, J. J., W. R. CLARK, AND R. D. ANDREWS. 1992. Factors associated with raccoon mortality in Iowa. Journal of Wildlife Management 56:693-699.

HUNTLEY, J., L. KARACOLOFF, A. KURST, AND S. OSER. 1995. The impact of the wildlife rabies epizootic on New York State: analysis of a raccoon rabies control and eradication plan using field vaccination. Unpublished report.

JOHNSTON, W. B., AND M. B. WALDEN. 1996. Results of a national survey of rabies control procedures. Journal of the American Veterinary Medical Association 208:1667-1672.

KREBS, J. W., J. S. SMITH, C. E. RUPPRECHT, AND J. E. CHILDS. 1998. Rabies surveillance in the United States during 1997. Journal of the American Veterinary Medical Association 213:1713-1728.

KREINDEL, S. M., M. MCGUILL, M. MELTZER, C. RUPPRECHT, AND A. DEMARIA, JR. 1998. The cost of rabies postexposure prophylaxis: one state's experience. Public Health Reports 113:247-251.

MASTERS, J. 1998. Impact of rabies epizootic on public service agencies in Niagara County. Unpublished Report. Niagara County Health Department.

MELTZER, M. I. 1996. Assessing the costs and benefits of an oral vaccine for raccoon rabies: a possible model. Emerging Infectious Disease 2:343-349.

MELTZER, M. I., AND C. E. RUPPRECHT. 1998. A review of the economics of the prevention and control of rabies, Part 1: Global impacts and rabies in humans. Pharmacoeconomics 14:365-383.

MELTZER, M. I., AND C. E. RUPPRECHT. 1998. A review of the economics of the prevention and control of rabies, Part 2: Rabies in dogs, livestock and wildlife. Pharmacoeconomics 14:481-498.

NATIONAL AGRICULTURAL STATISTICS SERVICE. 1999. 1997 Agricultural census: U.S. summary and state data. Volume 1. Geographic Area Series. Part 1. U.S. Department of Agriculture, Washington, D.C., USA.

NATIONAL AGRICULTURAL STATISTICS SERVICE. 1998. Agricultural Statistics 1998. U.S. Department of Agriculture, Washington, D.C., USA.

NETTLES, V. F., J. H. SHADDICK, K. SIKES, AND C. R. REYES. 1979. Rabies in translocated raccoons. American Journal of Public Health 69:601-602.

RUPPRECHT, C. E., AND J. S. SMITH. 1994. Raccoon rabies: the re-emergence of an epizootic in a densely populated area. Seminars in Virology 5:155-264.

SANDERSON, G. C., AND G. F. HUBERT, JR. 1982. Selected demographic characteristics of Illinois (U.S.A.) raccoons *(Procyon lotor)*. Pages 487-513 *in* J. A. Chapman and D. Pursely, editors. Worldwide furbearer conference proceedings. Maryland Wildlife Administration, Annapolis, Maryland, USA

SCHINNER, J. R., AND D. L. GAULEY. 1974. The ecology of urban raccoons in Cincinnati, Ohio. Pages 125-130 *in* A Symposium on Wildlife in an Urbanizing Environment. Massachusetts Cooperative Extension Service, Springfield, USA. Springfield, USA.

SHERMAN, K. M. 1990. Rabies control in Florida with special reference to innovative programs in other states. Florida Journal of Public Health II Fall, 1990:2-6.

STUEWER, F. W. 1943. Raccoons: their habits and management in Michigan. Ecological Monographs 13: 203-257.

TRIMARCHI, C. V. 1995. Raccoon rabies in New York State: patterns of the epizootic. New York Rabies Symposium, Response to Wildlife Rabies: The potential for wildlife rabies vaccination. Albany, USA.

TWITCHELL, A. A., AND H. H. DILL. 1949. One hundred raccoons from one hundred and two acres. Journal of Mammalogy 30:130-133.

UHAA, I. J., V. M. DATO, F. E. SORHAGE, J. W. BECKLEY, D. E. ROSCOE, R. D. GORSKY, AND D. B. FISHBEIN. 1992. Benefits and costs of using an orally absorbed vaccine to control rabies in raccoons. Journal of the American Veterinary Medical Association 201:1873-1882.

URBAN, D. 1970. Raccoon populations, movement patterns, and predation on a managed waterfowl marsh. Journal of Wildlife Management 34:372-382.

U.S. CENSUS BUREAU. 1998. Statistical abstract of the United States. 118th edition. U.S. Department of Commerce, Washington, D.C., USA.